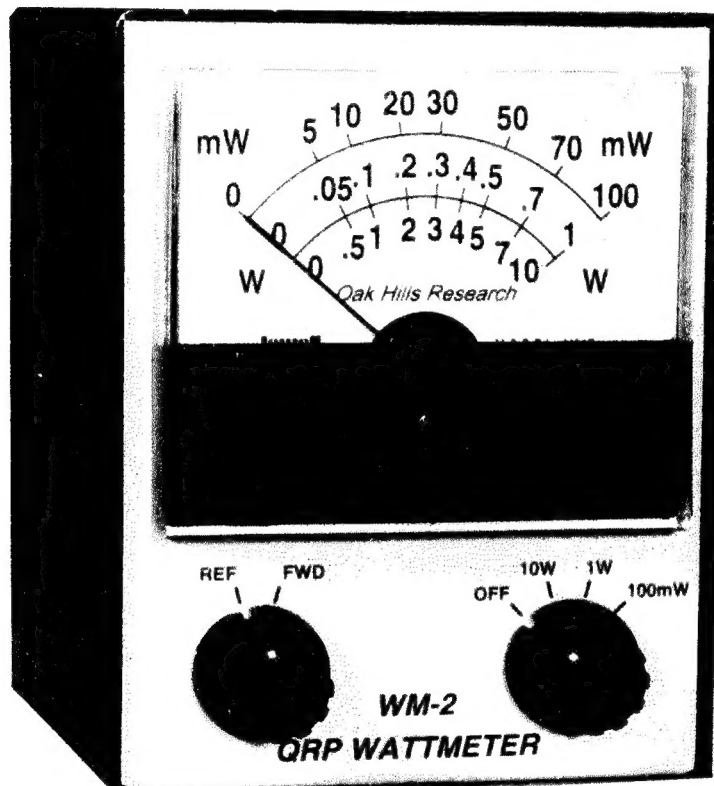


ASSEMBLY INSTRUCTIONS

WM-2 QRP WATTMETER



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Introduction

Thank you for purchasing the WM-2 wattmeter kit. The WM-2 was designed specifically for the QRP operator. The unit operates from 300 KHz to 54 MHz. It will measure forward and reflected power at QRP levels down to 5mW. You can select from three full scale power ranges of 10W, 1W or 100mW with an accuracy of $\pm 5\%$ of full scale. A rear panel switch allows you to select the internal 9V battery or external power jack for the operating voltage. The WM-2 now uses a very high quality American made 3" meter movement with a large easy to read scale. The meter circuit current drain is typically 1mA, making it great for portable use. The wattmeter can be left in-line permanently with very little loss. The kit is supplied with high quality Amphenol SO-239 connectors. The WM-2 is easy to build and align. The alignment consist of setting three voltages with your digital voltmeter. A source of RF is not required for alignment.

You will need the following tools to assemble your kit: normal hand tools which include long-nose pliers; diagonal cutters; GOOD wire strippers; phillips screwdriver; pliers; 25-30 watt pencil type soldering iron; ruler; magnifying glass; supply of *ROSIN CORE* solder. A desoldering bulb and desoldering braid are also helpful to have. You will also need a digital voltmeter for alignment.

Soldering is one of the most important operations you will perform while assembling your kit. About 95% of all kits returned to us for repair have problems caused by poor soldering. A good solder connection will form an electrical connection between two parts, such as a component lead and a circuit board foil. A bad solder connection will prevent an otherwise well assembled kit from operating properly. It is easy to make good solder connections if you follow a few simple rules. Use the correct type of soldering iron. A 25-30 watt pencil soldering iron with a 1/8 or 3/16 chisel tip works well. Keep the soldering iron tip clean. Wipe it often on a wet sponge or cloth; then apply solder to the tip to give the entire tip a wet look. This process is called tinning, and it will protect the tip and enable you to make good solder connections. When solder tends to "ball" or does not stick to the tip, the tip needs to be cleaned and retinned. **ALWAYS USE ROSIN CORE**, radio type solder (60:40 tin-lead content) for all the soldering in this kit. The warranty will be void and we will not service any kit in which acid core solder or paste has been used.

ASSEMBLY NOTES

The parts list contains a REF DES#. The REF DES# is used on the schematic diagram and PC board to identify individual parts. Some parts may be supplied on a tape. Use your cutters to cut the component leads from the tape. Never pull the components from the tape. All components are mounted on the component screen side of the board. All horizontal mounted components are positioned down against the board.

Use care when handling the cabinet parts. Some may have sharp edges. You should wear eye protection to prevent a cutoff lead clipping from flying up into your eye. As you cut component leads, hold on to the lead.

The WM-2 is not difficult to build. Just take your time and use common sense. Don't work too long at one time. Take frequent breaks. Take the time now to read through all the steps in this booklet before beginning construction of your kit. This will help you become familiar with the kit and may help prevent mistakes.

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BOARD ASSEMBLY

- (✓) Unpack the parts bags. Take inventory using the parts list. As you check parts off, it is helpful to lay out the parts in groups, resistors in one group, caps in another group and so on.
- (✓) Locate the PC board (40-205). Place it in front of you with T1 at the top.
- (✓) In the following steps, the word "install" means to install the part at the correct location, solder and trim the leads.
- (✓) Install the 100 ohm (brn-blk-brn-gld) resistor at R13.
- (✓) Install the two 51 ohm (grn-brn-blk-gld) resistors at R1 & R2.
- (✓) Install the 680 ohm (blu-gry-brn-gld) resistor at R12.
- (✓) Install the two 2.2K ohm (red-red-red-gld) resistors at R7 & R10.
- (✓) Install the 12K ohm (brn-red-org-gld) resistor at R9.
- (✓) Install the 47K ohm (yel-vio-org-gld) resistor at R5.
- (✓) Install the two 100K ohm (brn-blk-yel-gld) resistors at R3 & R4.
- (✓) Using two cutoff leads from a resistor, place a gentle arc in each wire and install at "JP1" and "TEST LOOP". Mount about 1/4" above the board.
- (✓) In the following step you will install the three 1N34A diodes. These diodes are fragile and can be easily damaged. Just put a gentle bend in each lead to match the hole spacing on the board. Also, be sure to match the green banded end with the banded end on the board.
- (✓) Install the three 1N34A diodes at D1, D2 & D4.
- (✓) Refer to Fig 4 for this step. Place the CA3160E IC on a hard surface on its side with the pins flat. Roll the IC on the surface so as to make the pins 90 deg to the body of the IC. Do the same on the other row of pins. Repeat this procedure on the LM358N IC. This makes it a lot easier to insert the IC into the holes in the board without bending under the pins. When you install the ICs, be sure you match the notch on the IC with the notch on the board. Install the CA3160E at U1 and the LM358N at U2. Solder all pins.

BOARD ASSEMBLY

- (✓) Install .01 μ F (103) mono caps at C1, C2, C3 and C5. The last .01 μ F mono cap will be installed later.
- (✓) Install the 200 ohm (201) trim pot at R14. It is not necessary to trim the leads on this or any of the trim pots after soldering.
- (✓) Install 5K ohm (502) trim pots at R8 & R11.
- (✓) Install the 100K ohm (104) at R6.
- (✓) Locate the length of the large red wire. Remove all the insulation. Cut a 2" length. Lay the wire down on the board at the location labeled "JUMPER" and mark the hole locations on the wire. Using your pliers, place a sharp bend in the wire at each marked location to form a "U" shaped jumper. Install the pre-bent jumper so it is down against the board.
- (✓) Install the 10 μ F electrolytic cap at C4. The long lead goes in the hole labeled "+".
- (✓) Locate the four small terminal pins. Notice there is a long and short section on each side of the small flange. From the TOP side of the board, insert the short section of the pin into the hole labeled "TERM 1". Be sure the pin is vertical. Solder and trim the pin. Be careful not to burn yourself on the hot pin. Install the remaining pins at TERM 2, TERM 3 and TERM 4.
- () Locate the length of RG58/u coax cable. Refer to Fig 3. Cut two lengths 2 1/4" long. Remove 1/2" of the black outer jacket from each end of each cable. Try not to cut into the braid when removing the outer jacket. Now push the braid back to loosen it up. Comb out the braid to straighten out the stranded wires. Twist the wires together to form a lead. At one end of each cable cut the braid off where it exits the black jacket. Now remove 1/4" of the inner conductor insulation from each end of each cable. If necessary, twist the inner conductor wires together. With your soldering iron, lightly tin the exposed wires on each cable including the braid. Set the prepared cables aside for now.

BOARD ASSEMBLY

- (✓) Locate the length of red #24 wire and the two black cores. Unroll it and straighten it out without putting any kinks in it. Cut two 10 1/2" lengths of this wire. Refer to assembly pictorial Figs 5, 6 & 7. Wind 12T of wire on each core. After winding the coils, trim both leads to 1" from the core. Completely tin each lead to the core as shown.
- (✓) Insert the end of the prepared coaxial cable with the braid removed through the center of one of the prepared coils. The black outer jacket should be centered in the coil. Place this coil/cable assembly over the board at location T1. Insert the two coil leads into the holes near the center and the braid lead into the hole labeled "BRAID". From the bottom side of the board, slightly pull on the coil leads and the braid lead just enough to remove any slack. Solder and trim the coil and braid leads. On the top of the board, the ends of the coax should intersect the vertical terminal pins at TERM 1 and TERM 2. Solder these connections. Trim off any excess lead length from the coax ends. Install the other coil and coax cable combination at T2 using the procedure.
- (✓) At this time all components (except wires) should be installed and soldered on the board. Take the time now to inspect the PC board for proper solder connections and for any solder bridges. **DO NOT** skip this step. It may save you some frustration later. NOTE: You should have a .01µf (103) mono cap left over. It will be installed later.
- (✓) At one end of the grey 8 conductor cable, cut the outer jacket back about 1" or enough to expose the wires. Start pulling the wires out of the jacket one or two at a time until all are removed. Discard the grey jacket. These wires will be used for all point to point connections.
- (✓) Cut the following wires to the indicated length:
- | | | | |
|-----|--------|-----|--------|
| BLK | 2 1/2" | RED | 4" |
| BLK | 3 1/2" | RED | 2 1/2" |
| BLK | 4" | RED | 2" |
| BLK | 1 1/4" | ORG | 1 1/2" |
| BRN | 2 3/4" | YEL | 2 1/4" |
| BRN | 3" | GRN | 1 1/2" |
| WHT | 2 1/4" | BLU | 5 1/2" |
- (✓) In the following step you will be removing insulation from the cut wires. Be sure to use a good quality pair of wire strippers for this. **DO NOT** use a knife or diagonal cutters to remove the insulation. You will constantly be repairing broken wires.

BOARD ASSEMBLY

- (✓) Remove 1/4" insulation from each end of each wire. At one end of each wire, use your soldering iron to lightly tin the exposed wires.
- (✓) Locate the rotary switch that has three terminal lugs on it. Position the switch with the terminal lugs facing you and the bent location lug on the front part of the switch to the right. See Fig 2. Place a small loop on the tinned end of the 2 3/4" BRN wire; 4" RED wire; 2 1/4" YEL wire. Install and solder the loop end of these wires on rotary switch S1 as shown in Fig 2. Set the switch aside for now.
- (✓) Position the remaining rotary switch so the location tab is on the left as shown in Fig 1. Place a small loop on the tinned end of the 4" BLK wire; 1 1/2" GRN wire; 2" ORG wire; 2 1/4" WHT wire; 5 1/2" BLU wire.
- (✓) Install a short jumper wire between lugs 4 & 5 and between lugs 5 & 7 as shown in Fig 1. Use a cutoff lead from a resistor or cap for these jumpers. Solder lugs 4 and 5. Install and solder the loop end of the wires on switch S2 as shown in Fig 1.
- () All wires to the board are installed from the top side. When you install wires on the board, be sure all the wire strands go into the hole. Also, it is best to install and solder the wires one at a time. Install the free end of the wires from switch S2 into the indicated holes as follows:

BLK	100mW	GRN	1W
WHT	S2A	BLU	will be connected later
ORG	S2B Wip		
- () Install the three wires from switch S1 as follows:

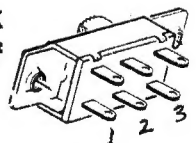
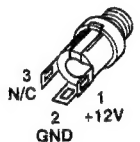
RED	S1/2
YEL	S1 Wip
BRN	S1/1
- () Install and solder the untinned end of the 2 1/2" RED wire and 2 1/2" BLK wire at the holes labeled "METER". The RED wire goes in the + hole. Set the board/switch assembly aside for now.

BOARD ASSEMBLY

- () Be careful when handling the chassis bottom. There may be sharp edges. Locate the chassis bottom. Use a small piece of sandpaper to remove any paint overspray from around the holes on the INSIDE of the chassis. DO NOT skip this step. A good ground connection is needed at these locations.
- () Place a #4 lockwasher on a 4-40 x 1/4" machine screw. From the bottom of the chassis, insert the screw through one of the four holes. On the inside of the chassis, place another #4 lockwasher on the screw and then start a 3/8" threaded spacer on the screw. Leave the spacer finger tight. Use the same procedure to install spacers at the other three locations.
- () Install an SO-239 connector in the rear panel hole labeled "TRANSMITTER". The large square flange goes on the outside of the rear panel. Position the connector so the opening in the center pin is facing up. Insert a 4-40 x 5/16" machine screw through one of the holes in the flange. On the inside of the chassis place a #4 lockwasher and a #4 hex on the screw. Repeat at the other three holes. Tighten all four screws and nuts.
- () Install the remaining SO-239 connector in the hole labeled "LOAD". Use the same procedure as before except in the upper right corner (front panel facing you) install a #4 solder lug instead of the #4 lockwasher. Position the solder lug so it is pointing up. Tighten all four screws and nuts.
- () Remove the large nut and washer from both rotary switch bushings. Now replace the nut on the bushings and screw them all the way on. Back them off about two turns.
- () Position the board/switch assembly on the inside of the chassis and insert the switch bushings through the front panel holes. The rotary switch with just three wires attached to it goes into the front panel hole labeled "REF FWD" and the other switch in the remaining hole. Secure the switches with a flat washer and control nut. Position the switches so the bent tab is facing outward. Tighten the control nuts.
- () Position the PC board over the four spacers. Start a 4-40 x 1/4" screw with a #4 lockwasher in each of the four mounting holes. Now tighten all four screws. Turn the chassis over and tighten the four screws on the bottom.

BOARD ASSEMBLY

- () Cut two 1" pieces of the large solid wire. Place the end of one of the wires in the center pin opening of the SO-239 connector near TERM 2. The other end will intersect the junction of the coax and the vertical terminal pin. Solder both connections. Trim off the excess length at TERM 2. Install the remaining 1" wire at the other SO-239 and TERM 1. Solder and trim.
- () Remove the nut and flat washer from the DC coaxial power connector. From the inside of the rear panel, insert the bushing of the connector through the hole labeled "EXT PWR". Position the connector so the center terminal is facing down. Secure with flat washer and nut.
- () From the inside of the rear panel, install the slide switch in the small rectangular hole. Secure with two small screws.
- () Connect one end of the previously prepared 1 1/4" BLK wire to terminal #2 of the coaxial power connector. Don't solder the connection yet. See drawing at right to identify terminal numbers on the power connector. Connect the other end to the near by solder lug. Don't solder the connection yet. Connect one end of the previously prepared 3 1/2" BLK wire to the solder lug. Solder the connection at the solder lug.
- () Connect one end of the previously prepared 2" RED wire to terminal #1 of the power connector. Don't solder the connection yet.
- () Cut both leads of the 1N4007 diode to 1/2". Bend both leads 90 deg. to the body of the diode. Connect the **BANDED** end to terminal #1 of the power connector. Solder the connection. Connect the other lead to terminal #2 of the power connector. Solder the connection.
- () See drawing at right to identify the numbered terminals on the slide switch. Connect and solder the free end of the RED wire coming from the power connector to terminal #3 of the slide switch. NOTE: When connecting and soldering wires to the slide switch be very careful not to cause a short circuit to the bent down tabs on the back of the switch. After all wires have been soldered to the terminals of the slide switch use your magnifying glass or light to be sure you have not created a short circuit.
- () Connect and solder one end of the previously prepared 3" BRN wire to terminal #1 of the slide switch.



BOARD ASSEMBLY

- () Connect and solder the free end of the BLU wire coming from S2 to terminal #2. Again, inspect the back of the slide switch to be sure there are no short circuits. NOTE: The top three terminals on the slide switch are not used.**
- () Position the black battery holder on the inside of the rear panel with the terminal lugs over the power connector. Insert a 4-40 x 1/4" screw through one of the holes in the battery holder and through the hole in the rear panel. Secure with a #4 hex nut. Repeat at the other mounting hole.**
- () Connect and solder the free end of the BRN wire to the bottom (+) terminal of the battery holder. Connect and solder the free end of the BLK wire coming from the solder lug to the other terminal of the battery holder.**
- () Use the supplied plastic cable ties to dress up the various wires coming from the PC board and the rotary switches. You MUST keep all wires away from transformers T1 and T2.**
- () Install the meter in the remaining holes in the front panel. Secure with the supplied hardware. Install a large solder lug on each of the meter terminal post. Position the solder lugs pointing down. Secure with the supplied hardware. Don't over tighten those NON-QRP nuts.**
- () Cut both leads of the remaining .01 μ F (103) mono cap to 1". Connect one lead to the (+) terminal and the other lead to the (-) terminal. Connect the RED and BLK wires coming from the PC board holes labeled "METER" to the meter. The RED wire goes to the positive terminal. Solder both connections. Bend the .01 μ F cap downward. NOTE: The (+) meter terminal is on the left (with rear panel facing you).**
- () Turn both shafts on the two front panel controls full left. Place a knob on the "REF FWD" shaft. Line up the notch in the knob with the REF line. Tighten the set screw. Place a knob on the other switch shaft and line up the notch with the OFF line. Tighten the set screw.**
- () Turn the WM-2 over. Peel one of the cabinet feet from the backing paper and place it about 1/2" in from each corner. Repeat at the other three corners.**

BOARD ASSEMBLY

- () Connect one lead of your ohmmeter to the chassis. Touch the other lead to the BLU wire at terminal #2 of the slide switch. Move the switch to both positions. You should read infinite ohms. If you are reading a low value of resistance at this point, you have a short circuit somewhere. This condition must be corrected before you apply power.
- () This completes assembly of the wattmeter.

ALIGNMENT

- () Locate the molded power cable assembly. The *POSITIVE* lead is connected to the center pin of the molded plug. Use your ohmmeter to identify the *POSITIVE* lead. Be sure this *POSITIVE* lead connects to the *POSITIVE* terminal of your power supply. If the positive terminal of your power supply is not fused, you should add an in-line fuse holder with a 1/4A fuse in the positive supply line.
- () Attach the BLACK lead from your digital voltmeter to chassis ground. Carefully attach the other lead to the "TEST LOOP". You can use an alligator clip type jumper lead to connect to the test point if it is difficult to connect your probe directly to the test loop.
- () Attach the molded power cable to your power supply observing the correct polarity. Connect the molded plug to the WM-2. You can also install the 9V battery and forget the power supply. The WM-2 will operate with a voltage from 9 - 13.6VDC.
- () Apply power to the wattmeter. Select the power source you have elected to use with the rear panel slide switch.
- () Be sure the WM-2 is in the off position. Check the position of the meter needle. If it is not resting on the zero mark, use the zero adjustment screw on the meter face plate to zero it.
- () Place the range switch on the front panel of the WM-2 to the 10W position. Adjust pot R6 for a reading of 2.56V on the voltmeter. Adjust pot R8 for a full scale reading of 10W on the wattmeter.
- () Adjust pot R6 for a reading of .800V on the voltmeter. Place the range switch in the 1W position. Adjust pot R11 for a full scale reading of 1W on the wattmeter.

ALIGNMENT

- () Adjust pot R6 for a reading of .251V on the voltmeter. Place the range switch in the 100mW position. Adjust pot R14 for a full scale reading of 100mW on the wattmeter.
- () Turn the WM-2 to the off position. Without disturbing any of the pot settings, very carefully cut jumper JP1. JP1 is right next to pot R6. DO NOT CUT THE TEST LOOP. Remove your voltmeter lead from the test loop. Alignment is now complete.
- () Position the cover over the chassis and line up the two holes on the sides. Secure the cover with the two black 1/4" sheet screws. This completes the assembly and alignment of your WM-2.

OPERATION

The operation of the WM-2 is very easy and straightforward. Always start a measurement with the wattmeter in the 10W position and then switch to a lower position. To measure power, select the appropriate scale. Put the FWD/REF switch in the FWD position. To read the reflected power, simply set the switch to the REF position. The power flowing in the line is the forward reading minus the reflected reading. To adjust a transmatch, put the WM-2 between the transmitter and transmatch and adjust the transmatch for the lowest reflected power.

This directional wattmeter can do anything an SWR meter can do, and much more. Because you can measure power anywhere in a system, you can use the wattmeter to find cable and transmatch losses, measure transmitter power, measure power at various points in a transmitter during the building process and much more.

The WM-2 will operate on any voltage between 9 - 13.6VDC. The meter circuit draws very little current, typically 1.2mA on stand-by. The input and output impedance is 50 ohms.

I hope you have enjoyed building the WM-2 and that it provides many years of reliable service.

Dick Witzke, KE8KL

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Oak Hills Research

WM-2 Parts List

40-205

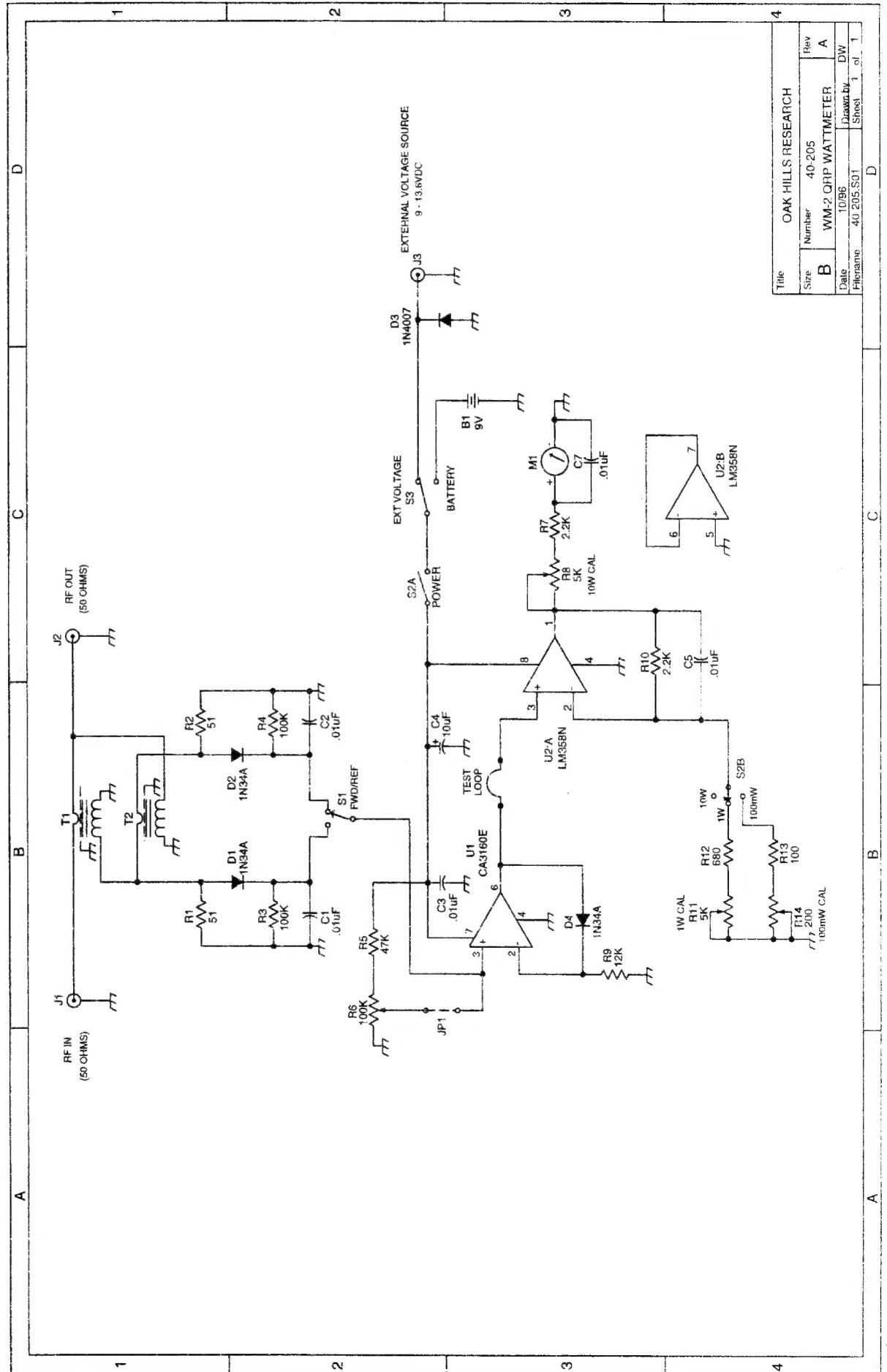
QTY	OHR P/N	DESCRIPTION	REF DES	MARKINGS
1	6-101-14	100 Ohm 5% 1/4W Resistor	R13	Brn-Blk-Brn-Gld
2	6-510-14	51 Ohm 5% 1/4W Resistor	R1, R2	Grn-Brn-Blk-Gld
1	6-680-14	680 Ohm 5% 1/4W Resistor	R12	Blu-Gry-Brn-Gld
2	6-222-14	2.2K Ohm 5% 1/4W Resistor	R7, R10	Red-Red-Red-Gld
1	6-123-14	12K Ohm 5% 1/4W Resistor	R9	Brn-Red-Org-Gld
1	6-473-14	47K Ohm 5% 1/4W Resistor	R5	Yel-Vio-Org-Gld
2	6-104-14	100K Ohm 5% 1/4W Resistor	R3, R4	Brn-Blk-Yel-Gld
1	POT2	200 Ohm PC Pot	R14	201
2	POT6	5K Ohm PC Pot	R8, R11	502
1	POT10	100K Ohm PC Pot	R6	104
5	MC101	.01µF Mono Cap	C1, C2, C3, C5, C7,	103
1	CE06	10µF Electrolytic Cap	C4	
3	1N34A	Germ Diode	D1, D2, D4	1N34A
1	1N4007	Silicon Diode	D3	1N4007
1	CA3160E	Op-Amp	U1	CA3160E
1	LM358N	Op-Amp	U2	LM358N
2	FT50-43	Ferrite Core/Wire	T1, T2	12T #24 Wire
1	K042	3" Panel Meter	M1	
1	K168	4 Pos Rotary Switch	S2	
1	K167	2 Pos rotary Switch	S1	
1	K353	DPDT Slide Switch	S3	
2	K092	SO-239 Connector	J1, J2	
1	K293	DC Power Jack	J3	
1	K157	Battery Holder		
1	K348	Molded Power Cable Assy		
4	K355	Small Pin Terminal		
2	K354	Small Screw		
4	K132	Cabinet Feet		
3	K145	Plastic Cable Tie		

Oak Hills Research

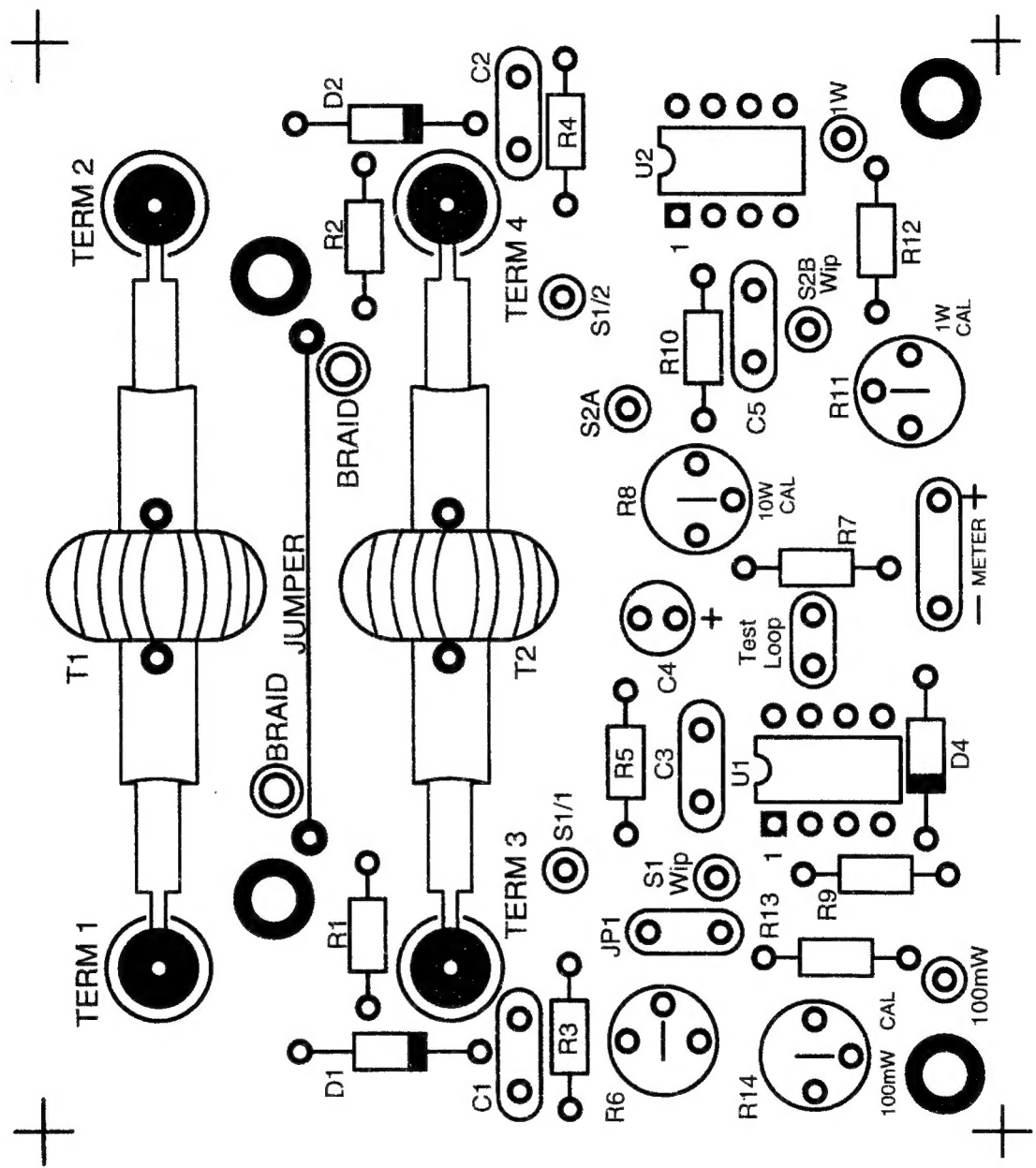
WM-2 Parts List

40-205

QTY	OHR P/N	DESCRIPTION	REF DES	MARKINGS
2	K128	Large Solder Lug For Meter		
1	K004	Small #4 Solder Lug		
10"	K137	RG58/U Coax Cable		
4	K147	Round Alum Spacer		
10	K162	4-40 x 1/4" Machine Screw		
8	K056	4-40 x 5/16" Machine Screw		
10	K059	#4 Hex Nut		
20	K058	#4 Lockwasher		
2	K129	Black #6 1/4" Sheet Screw		
1	40-205	PC Board		
12"	K049	8 Cond Cable		
1	10-109-A	Cabinet Bottom		
1	10-109-B	Cabinet Cover		
2	K011	Knobs		
2	K012	Large Control Nut		
6"		Large Solid Wire		



Title OAK HILLS RESEARCH			
Size B	Number 40-205	Rev A	
Date 10/96	WM-2 QRP WATTMETER	Drawn by DW	
File name 40-205.S01	Sheet 1 of 1		

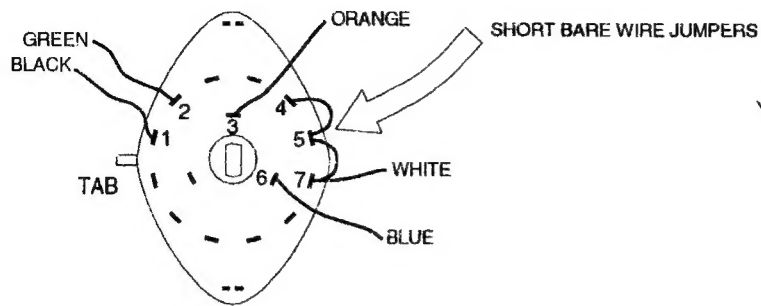


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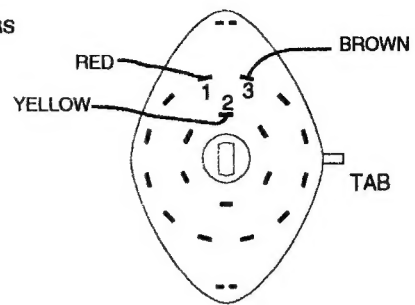
40-205

WM-2

ASSEMBLY PICTORIAL



REAR VIEW
S2
FIG 1



REAR VIEW
S1
FIG 2



FIG 3

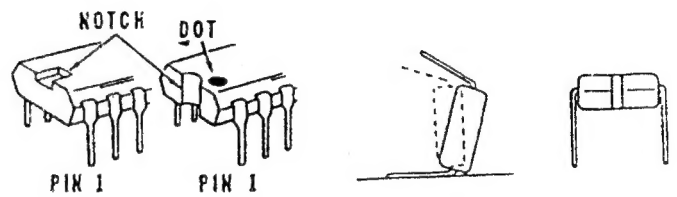
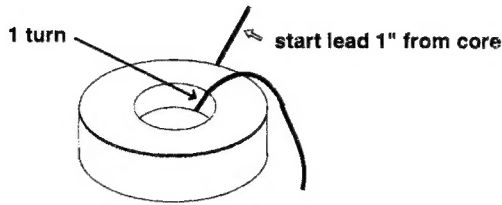


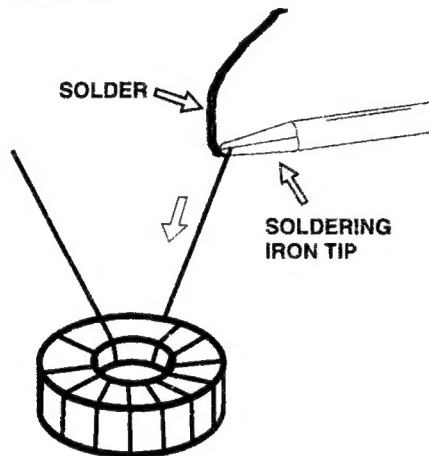
FIG 4

ASSEMBLY PICTORIAL



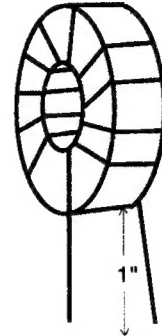
Everytime the wires pass through the center of the core, count that as one turn. Turns are always counted on the inside of the core.

FIG 5



To tin the lead, place the soldering iron tip and solder on the lead near the end and feed a small amount of solder to the tip and lead. Move the tip back and forth a small amount. Keep feeding more solder to the tip and lead. The lead will start to tin. As it does, slowly move the tip and solder up the lead toward the core. As you do, the lead will become tinned. Continue until the entire lead is tinned. Repeat with the other lead or leads.

FIG 7



After winding, trim both leads to 1" from core. Tin each lead to the core.

FIG 6